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MODULAR ELECTRICAL DEVICE

Background

The present development relates to a modular electrical device and, more particularly, to a modular electrical device that is highly resistant to ingress of water, oil, debris, dirt and other contaminants encountered in manufacturing and other environments without use of a separate enclosure. As described herein, one application for a device formed in accordance with the present development is as a modular distributed input/output (I/O) assembly that forms a part of or is connected to an industrial automation control system. Those of ordinary skill in the art will recognize that the device has other applications, and it is not intended that the device be limited to use for any particular application.

In connection with industrial automation control systems and other electrical systems, it has been deemed desirable to provide electrical devices for transmission/input/output of data signals and/or power voltages that are distributed throughout a manufacturing, distribution or other facility and located directly on or adjacent machines performing manufacturing, distribution, inspection and/or other processes. It has also been found that, in certain cases, these electrical devices should be modular to allow for customization, re-configuration and repair/replacement as needed during installation or later. This modularity improves usability but can lead to ingress of water, oil, dirt, debris, and/or other contaminants into the device, with highly undesirable consequences. Furthermore, modular components can undesirably separate owing to vibration, impact, cable stresses or other external forces.

Certain modular electrical devices are housed within an enclosure that provides secure mounting and also protects the device from environmental contamination. Use of an enclosure is often not practicable due to space constraints, ease of installation/re-configuration/repair and/or other concerns.

Contamination-resistant modular electrical devices are known. One example is a distributed input/output (I/O) assembly available commercially from Rockwell

Automation under the trademark 1798 FLEX Armor™. I/O circuitry is packaged in I/O modules, and the I/O modules of an assembly plug into a common baseplate. The baseplates is available in sizes of 2, 4, 6, and 8 I/O module slots. An I/O adapter module and a field termination module plug into two slots of the baseplate. The baseplate holds the modules in place and provides the backplane for the assembly. No enclosure is required because each module is packaged in a sealed housing rated for IP65/67 and NEMA 4X (indoor/outdoor) and 6P. While the FLEX Armor™ I/O system has enjoyed widespread commercial success, certain modifications have been deemed desirable, at least for particular applications. For example, with the FLEX Armor™ system, the baseplates are available in units of 2, 4, 6 and 8 I/O modules. Also, to maintain the environmental ratings, all slots on the baseplate must be filled with either a live I/O module or a filler module.

Other modular electrical devices that are resistant to environmental contamination are known and available commercially from other sources. Some of these devices rely on conventional O-ring seals or other types of seals that provide only a single sealing dynamic at each sealing location, i.e., only radial/lateral sealing or only axial/compressive sealing. In certain cases, these seals are susceptible to leakage, especially when the modular components are subjected to vibration or other external forces such as lateral and/or axial separation forces. Other known devices utilize conventional O-rings seals or other seals that are positioned in a manner where they can be damaged or dislodged during handling, installation or during repair/replacement operations. Another drawback associated with some of these conventional modular electrical devices is that the seal is connected to or forms a part of the permanent components of the system, instead of the replaceable components. As such, use of a replacement component does not automatically result in use of a new seal. Known modular electrical devices have also been found to be sub-optimal insofar as operative mating of the components is concerned. Some require use of separate fasteners such as screws or the like which can be inconvenient and can lead to component damage if the fasteners are over-torqued. Other systems rely on a simple friction fit between

components, and this can lead to unintended separation of the components such as when the components are mounted in an inverted position and/or in response to cable strain. Known systems have also not provided base components that are conveniently and securely mechanically with each other to ensure proper definition of the module mounting locations and to minimize undesired movement between base components. Examples of known modular electrical devices can be found in the following documents: U.S. Patent No. 6,475,036; U.S. Patent Application Publication No. 2002/0182942; U.S. Patent No. 4,707,043; German Utility Model No. DE29703367U1; and, German Utility Model No. DE29607525U1.

In light of the foregoing, it has been deemed desirable to provide a new and improved modular base for an electrical device, and/or an electrical device including the modular base and removable modules with improved operative mating of components so as to facilitate use and improve ingress protection.

Summary

In accordance with one aspect of the present development, a modular electrical device comprises a modular base comprising a plurality of base components adapted to be arranged relative to each other so as to define a backplane comprising at least one module mounting location, wherein the at least one mounting location comprises a first electrical base connector of one base component and a second electrical base connector of another base component. At least one removable module is adapted to be respectively removably connected to the backplane in the at least one mounting location. The module comprises: (i) a first module connector adapted to be mated with the first electrical base connector to form a mated pair of first connectors; and, (ii) a second module connector adapted to be mated with the second electrical base connector to form a mated pair of second connectors. The module is adapted to electrically interconnect said first and second electrical base connectors of the mounting location. A coupling device is connected to the backplane and is located in the

mounting location. The coupling device is adapted to releasably secure the module to the backplane.

In accordance with another aspect of the present development, a modular base for an electrical device comprises at least two separate base components adapted for selective mechanical mating via corresponding male and female portions so as to define a backplane that comprises at least one module mounting location. Each of the at least two base components comprises at least one electrical connector. The at least one mounting location comprises first and second electrical connectors that form a part of respective first and second ones of said at least two base components.

Brief Description of the Drawings

The development comprises components and arrangements of components, preferred embodiments of which are disclosed herein and shown in the drawings that form a part hereof, wherein:

FIG. 1 is an isometric view of a modular electrical device formed in accordance with the present development;

FIG. 2 is similar to FIG. 1, with all removable modules thereof not shown to reveal the underlying base assembly;

FIGS. 3, 4 and 5 are isometric views of an adapter base component, an intermediate base component, and an end base component, respectively;

FIGS. 6, 7 and 8 are top plan, bottom plan and isometric views, respectively, of one example of a removable module component formed in accordance with the present development;

FIG. 9 is a sectional view as taken along line 9-9 of FIG. 6;

FIG. 10 is a side view showing a removable module separated from a portion of the base assembly to which it is adapted to be operatively mated;

FIG. 11 is an isometric view that shows the removable module and portion of the base assembly of FIG. 10;

FIG. 12 is similar to FIG. 4, but shows the intermediate base component with an upper surface thereof partially removed to reveal a coupling device formed in accordance with the present development;

FIG. 13 is a bottom plan view of the intermediate base component shown in FIG. 12;

FIG. 14 is a side view of a removable module mated with the coupling device of an intermediate or end base component, with portions in the foreground not shown and portions of the base component broken away for clarity;

FIG. 15 is an isometric view of a sliding lock member component that forms a part of the coupling device;

FIG. 16A and 16B diagrammatically illustrate use of the coupling device to eject a removable module in accordance with the present invention;

FIG. 17A is an isometric view of the inner housing portion of a removable module;

FIG. 17B is a sectional view as taken along line B-B of FIG. 17A;

FIG. 17C is similar to FIG. 17B but shows an isometric sectional view;

FIG. 18A is a top plan view of an alternative seal formed in accordance with the present development as operatively mounted to a base component;

FIG. 18B is a sectional view as taken along line B-B of FIG. 18A; and,

FIGS. 19A and 19B show a modular electrical device formed in accordance with an alternative embodiment of the present development.

Detailed Description

FIG. 1 illustrates a modular electrical device **10** in accordance with the present development. The device **10** comprises a modular base assembly **12** and one or more removable modules **14**. The modules **14** are releasably connected to the base assembly **12** and can be selectively removed to reveal the underlying base assembly **12** as shown in FIG. 2. The device **10** can be electrically configured to perform any of a wide variety of functions, and it is not intended that the development as described

herein be limited to any particular electrical function. For ease of explaining the development **10**, however, reference is made herein to use of the device **10** as a distributed modular input/output (I/O) assembly as used, e.g., as part of an industrial automation control system.

FIG. 2 shows that the base assembly **12** comprises a plurality of modular base components **12c** (i.e., more than one) arranged adjacent each other, preferably mechanically interconnected with each other, so as to define a field bus or backplane **20**. The backplane **20** defines a plurality of module mounting locations such as the four mounting locations **M1 – M4** shown in FIG. 2. As is described in full detail below, each mounting location is adapted to receive and releasably retain one of the removable modules **14**.

In a typical installation, the base assembly **12** is defined by a single adapter base component **12c1**, one or more intermediate base components **12c2** and a single end base component **12c3**. The number of intermediate base components **12c2** is varied to control the number of mounting locations **M1-M4** defined by the backplane **20**.

An adapter base component **12c1** is shown separately in FIG. 3 and comprises a body **30** to which network (e.g., data/power) connectors **30a** are affixed. The network connectors **30a** are conventional and provide input and/or output of electrical power and data to/from an external network. The adapter base component **12c1** further comprises a first base connector **30b1** including one or more contacts **30c** which can comprise, e.g., male or female contacts. The base connector **30b1** is shown as a male plug connector with female contacts **30c**, but could also be a female socket connector with male pin contacts. The network connectors **30a** and contacts **30c** are electrically connected to electronic circuitry **30d** housed within the body **30** as shown by paths **30p**. LED's or other visual output devices **30e** are connected to and/or form part of the circuitry and provide visual output on the status of the circuitry **30d**.

The network connectors **30a** provide for input and output of power and/or data between the circuitry **30d** and other portions of the modular electrical device **10** and an external network, as controlled by the electronic circuitry **30d**, while the first base

connector **30b1** and contacts **30c** thereof provide for input and output of data and/or power between the adapter base component **12c1** and other portions of the device **10**, such as the intermediate base component(s) **12c2** and end base component **12c3** of the base assembly **12**, and the removable modules **14** connected thereto. In one example, the modular electrical device **10** is provided as a distributed I/O assembly for an industrial automation network, and the network connectors **30a** and circuitry **30d** are configured to connect and communicate with the external automation network. The electronic circuitry **30d** and, except for the accessible mating portions, the network connectors **30a** and contacts **30c**, are sealed within the body by potting compound or other means to protect against environmental contamination.

The body **30** of the adapter base component **12c1** comprises a first puzzle-piece connector structure **P1** defined by a first peripheral edge **30e1**. The first puzzle-piece connector structure **P1** comprises one or more male projections **P1a** and female recesses **P1b**. The first base connector **30b1** is located on one of the male projections **P1a**.

Figure 4 illustrates an intermediate base component **12c2**. The intermediate base component comprises a body **32** which includes both first and second base connectors **30b1,30b2** each including one or more contacts **30c** which can comprise, e.g., male or female contacts. The base connectors **30b1,30b2** can be male (plug) connectors (as shown) or female (socket) connectors. Each contact **30c** of the first base connector **30b1** is electrically coupled to a corresponding contact **30c** of the second base connector **30b2** by conductor bars **32d** or the like which are sealed in the body **32** by potting compound or other means.

The body **32** of component **12c2** comprises a first peripheral edge **32e1** that also defines the first puzzle-piece connector structure **P1** described above. The body **32** further comprises a second peripheral edge **32e2**, located opposite the first peripheral edge, that defines a second puzzle-piece connector structure **P2** that includes one or more male projections **P2a** and female recesses **P2b** that are conformed to mate closely with corresponding male/female structures **P1a,P1b** of the first puzzle-piece

structure **P1** in only a single possible position. As such, the second puzzle-piece structure **P2** of an intermediate base component **12c2** is mated with the first puzzle-piece structure **P1** of the adapter base component **12c1** or another intermediate base component **12c2** as shown in FIG. 2.

Figure 5 illustrates an end base component **12c3**. The end base component comprises a body **34** which includes only a second base connector **30b2** having one or more contacts **30c** which can comprise, e.g., male or female contacts. The base connector **30b2** can be male (plug) connector (as shown) or female (socket) connector. In certain cases, the contacts **30c** of the end base module **12c3** can be non-functional (e.g., grounded through one or more resistors or otherwise) because they are located at the terminal end of the backplane **20**.

The body **34** comprises a first peripheral edge **34e1** that is non-functional and further comprises a second peripheral edge **32e2**, located opposite the first peripheral edge, that defines the second puzzle-piece connector structure **P2** as described above, including the one or more male projections **P2a** and female recesses **P2b** that are conformed to mate precisely and in only one possible position with corresponding male/female structures **P1a,P1b** of the first puzzle-piece structure **P1**. As such, the second puzzle-piece structure **P2** of the end base component **12c3** is mated with the first puzzle-piece structure **P1** of the adapter base component **12c1** or an intermediate base component **12c2** as shown in FIG. 2.

Referring again to FIG. 2, it can be seen that when the backplane **20** is constructed by the adapter base component **12c1**, at least one intermediate base component **12c2** and an end base component **12c3**, the mounting locations **M1-M4** each comprises a corresponding pair of base connectors **30b1,30b2**, i.e., a first base connector **30b1** from a first base component **12c** and a second base connector **30b2** from a second, adjacent base component **12c**. The backplane **20** can alternatively comprise only the adapter base component **12c1** and the end base component **12c3** so as to comprise only a single mounting location. Corresponding pairs of base connectors **30b1,30b2** defining each mounting location **M1-M4** are electrically

connected only through the removable modules **14**, when the modules are mated to the backplane **20**. The various mating puzzle-piece structures **P1,P2** mechanically interconnect the base components **12c1,12c2,12c3**, and ensure proper spacing and alignment of the corresponding pairs of base connectors **30b1,30b2** to define the mounting locations **M1-M4** to allow for releasable mating of a module **14**. Each base component **12c1,12c2,12c3** includes at least one aperture or other fastener-receiving location **12f** adapted to receive a screw, rivet, clip, pin or other fastener or fastening means for fixedly securing the base component **12c1,12c2,12c3** to a support surface.

With reference again to FIG. 2, the base connectors **30b1,30b2** include outer surfaces **36b1,36b2** and transverse end walls **38b1,38b2**, respectively. As shown, the base connectors **30b1,30b2** are frusto-conical in shape, with the outer surfaces **36b1,36b2** converging slightly (e.g., at a 1 degree angle) moving toward the transverse end walls **38b1,38b2**, but the outer surfaces **36b1,36b2** can also be purely cylindrical or otherwise shaped. The frusto-conical shape is thought to facilitate sealing and unsealing between the connectors **30b1,30b1** and a module **14** mated therewith as described below. The end walls **38b1,38b2** define apertures **39**, and the contacts **30c** are located within these apertures (for female contacts as shown) or project through these apertures (for male contacts).

FIGS. 6-9 illustrate one example of a removable module **14** formed in accordance with the present development. Each module **14** comprises a housing **40** constructed from inner and outer housing members **40a,40b** that are inter-fitted with each other to define an enclosed interior space **42** (FIG. 9) in which electronic circuitry **44** is located.

A plurality of connectors **46** are operably connected to the circuitry **44** and project through the outer housing member **40b** so as to be adapted for mating with corresponding cable connectors from external devices. The circuitry and connectors **44,46** are adapted for any desired electrical application. In one example, each module **14** performs as an industrial automation I/O module to which field devices and the like are connected via connectors **46**, and the circuitry **44** is configured for this purpose.

FIG. 1 shows a plurality of differently configured removable modules **14** including different types and arrangements of circuitry **44** and connectors **46**. Regardless of the configuration, modules **14** typically comprises a visual indicators such as LED's **48a** that provide visual output signals concerning the state of the circuitry **44** and marker holders **48b** used for labeling connectors **46** or for other purposes.

The housing **40** is sealed against ingress of environmental contaminants. The circuitry **44** and connectors **46** are potted within the outer housing member **40b** or otherwise sealed in place. The inner housing member **40a** is then sealed within the outer housing member, preferably by both mechanical and adhesive means, to provide the sealed interior space **42**. With reference to the sectional view of FIG. 9, it can be seen that the inner housing member **40a** is adapted for nesting within the outer housing member **40b** and comprises a plurality of tabs **50a** that are received in corresponding recesses **50b** such as notches, or apertures defined by the outer housing member **40b** so that the housing members **40a,40b** are mechanically interlocked with a close snap-fit. The tabs **50a** can alternatively project from the outer housing **40b** and the recesses **50b** can be defined in the inner housing **40a**. Furthermore, the inner housing member **40a** comprises a continuous wall **52a** projecting outwardly therefrom that is received within a corresponding continuously extending groove **52b** defined by the outer housing member **40b**. The joint at the junction of the wall **52a** and groove **52b** is sealed with a gasket or, preferably, with an adhesive and/or sealant such as, e.g., epoxy.

The housings **30,32,34** of the base components **12c1,12c2,12c3** and the inner and outer housing members **40a,40b** of the removable modules **14** are preferably defined as molded polymeric constructions utilizing any of a wide variety of polymeric materials in an injection molding process. One suitable material is glass-filled polyester, although it is not intended that the development be limited to such material or any other material.

As noted above, each module **14** is adapted for releasable connection to the backplane **20** of the base assembly **12**. To this end, each releasable module **14** comprises first and second module connectors **60b1,60b2** (see e.g., FIGS. 7,8) that are

adapted to mate respectively with a corresponding pair of first and second base connectors **30b1,30b2** of the backplane **20** at each mounting location **M1-M4**. In the illustrated embodiment, the first and second module connectors **60b1,60b2** are female or socket connectors comprising a plurality of male (as shown) or female contacts **60c**, wherein the contacts **60c** are electrically coupled to the module circuitry **44** and/or to other contacts **60c** by paths **44p** as shown in FIG. 7. Each base connector **60b1,60b2** is dimensioned and conformed for mating with a base connector **30b1,30b2** of the backplane **20**, so that the contacts **60c** mate with corresponding contacts **30c** of the base connectors **30b1,30b2** to establish electrical connection between the backplane **20** and the modules **14**. In this manner, the modules **14** act as and provide electrical links by which the individual base components **12c** are electrically interconnected to each other through their base connectors **30b1,30b2** so that data and/or power can flow from each module **14** to each other module **14**, from each base component **12c** to each other base component **12c**, and/or from each module **14** to each base component **12c**, including the adapter base component **12c1** and circuitry **30d** thereof as required for use of the device **10**.

FIGS. 10 and 11 are provided to show the relationship of a removable module **14** to the backplane **20** of base components **12c** as the removable module is about to be connected to the backplane. There, it can be seen that the mounting location **M2** of the backplane **20** is defined by base connectors **30b1,30b2** of interlocked base components **12c2**. The connectors **60b1,60b2** of removable module **14** are adapted to mate with the base connectors **30b1,30b2**, respectively, so that module spans the base connectors **30b1,30b2**. Of course, the electrical conductors **32d** of each base component **12c2** interconnect each of the base connectors **30b1,30b2** of the mounting location **M2** to the other base connector **30b2,30b1** on the same base component.

When a removable module **14** is operatively mated to the backplane **20** as shown in FIG. 1, it is releasably interlocked to one of the base components **12c** to prevent unintended separation of the module **14** from the backplane **20** by gravity, vibration, impact, vandalism, cable stresses and/or other external forces. FIGS. 2, 4

and 5 illustrate that each intermediate base component **12c2** and the end base component **12c3** comprises a coupling device **70** adapted to receive and retain a portion of a removable module **14** to connect the module to the base component **12c2,12c3** to prevent unintended disconnection. FIGS. 7, 8 and 10 clearly show that each module **14** comprises at least one and, preferably, at least two coupling projections such as spaced-apart hooks **82a,82b** that project outwardly from an inner surface **14s** thereof (the inner surface **14s** is defined as the surface of module **14** that contacts and/or is located adjacent the backplane **20** when the module **14** is mated to the backplane). These first and second hooks **82a,82b** are received into first and second slots **72a,72b** (FIGS. 4,5) of the base component housing **32,34** and are retained by the coupling device **70** when the module **14** is operatively connected to the backplane **20**.

The structure and operation of the coupling device **70** and use of same to operably couple a module **14** to the backplane **20** is explained further with reference to FIGS. 12 – 16B, using an intermediate base component **12c2** as an example. Those of ordinary skill in the art will recognize that the coupling device **70** of an end base module **12c3** is structured and functions identically. In FIG. 12, portions of the housing **32** are broken away to reveal the coupling device **70**. The coupling device **70** comprises a lock member **74** that is slidably connected to the housing **32** and adapted for reciprocating sliding movement between a first or "locked" position (FIGS. 12,16A) and a second or "release" position (FIG. 16B). The lock member **74** is preferably spring-biased into the first position.

FIG. 15 shows the lock member **74** by itself. In the illustrated embodiment, the lock member comprises a one-piece molded polymeric construction comprising first and second ends **74a,74b** separated from each other by a spring portion **74c**. The spring-biasing can be supplied by a separate spring or other resilient element but, in the illustrated embodiment, the biasing is provided by the spring portion **74c** that is defined as a part of the one-piece molded plastic lock member. One suitable polymeric material for molding the lock member is acetal, although other materials are contemplated and

can be used. It is not intended that the development be limited to a one-piece molded polymeric lock member, and the lock member can be defined from other materials and/or fabricated from multiple pieces, and the term "member" as used herein is not intended to be limited to a one-piece structure.

In the example shown herein, the spring portion **74c** comprises a frame **74d** that defines an open space **74e**. At least one and, preferably, a plurallity of fingers **74f** project from the frame **74d** into the space and terminate in free distal ends comprising feet **74g** defined in the form of a post or other structure. With reference now to FIGS. 12 and 13, the feet **74g** are engaged with bosses **74i** or other portions of the body **32** of the base component **12c** so as to be restrained against sliding movement with other portions of the lock member **74**. Except for the feet **74g**, the lock member **74** is slidably movable relative to the body **32** of the base component **12c** between the first and second positions as indicated by the arrow **74j**, by exertion of force on the actuator portion **74k** of the lock member that projects outwardly away from the housing **32**. Thus, when the actuator **74k** is pulled outwardly away from the housing (FIG. 16B), the lock member **74** slides from its normal first position to its second "release" position, while the fingers **74f** resiliently deflect owing to the immovable engagement of the feet **74g** with the body **32** of the base component **12c**. Upon release of the actuator **74k**, the natural resilience of the fingers **74f** returns them to their original shape or "home" position as shown in FIGS. 12 and 13 so as to move the lock member **74** back to its first "locked" position.

The lock member **74** comprises first and second latch portions **74p1,74p2** that are conformed and dimensioned and otherwise adapted to receive and retain the respective first and second hooks or other projections **82a,82b** of the module **14**. The first and second latch portions **74p1,74p2** are located respectively in the slots **72a,72b** of the base component housings **32,34**.

FIG. 14 shows a module **14** operatively mated to the backplane **20** in a mounting location **M1-M4**, with the coupling projections **82a,82b** thereof mated with and retained by the first and second latch portions **74p1,74p2**, respectively. The first and second

latch portions are adapted to mate with the first and second hooks **82a,82b** and thus comprise hook-like structures oriented oppositely relative to the hooks **82a,82b** of the modules **14**. The first and second latch portions **74p1,74p2** are each defined with a sloped outer surface **76k1,76k2** oriented and located so that, during installation of a module **14** to the backplane **20**, the projections **82a,82b** of the module engage the sloped surfaces **76k1,76k2** and urge the lock member **74** out of its natural first position toward its second position until the module **14** is fully seated against the backplane **20**, at which time the spring portion **74c** of the lock member **74** biases the lock member back to its first position so that the latch members **74p1,74p2** engage the hooks **82a,82b**, respectively, with a snap-fit so that a user received tactile feedback of full and proper installation of the module **14** to the backplane **20**.

As shown in FIG. 14, when a removable module **14** is fully operatively seated against a component **12c** of the backplane **20**, the first and second hooks **82a,82b** thereof are engaged with the first and second latch members **74p1,74p2**. The lock member **74** also functions as a module ejector and, thus, comprises one or more ejection surfaces such as the first and second ejection ramps **74r1,74r2** (see also FIGS. 4,5) conformed and arranged to engage the first and second hooks **82a,82b** or another part of the module **14** when the lock member **74** is moved toward and into its second operative position. In the illustrated embodiment, the module coupling hooks **82a,82b** comprise respective ejection surfaces **84a,84b** (see FIGS. 10,14) that lie adjacent the ejection ramps **74r1,74r2**. It is preferred that the ejection surfaces **84a,84b** and ejection ramps **74r1,74r2** be conformed as smooth mating sloped ramp surfaces.

With reference now to FIG. 14 and also FIGS. 16A and 16B, when the lock member is moved from its first or "locked" position (FIGS. 14,16A) to its second or "release" position (FIG. 16B), the latch portions **74p1,74p2** disengage from hooks **82a,82b** to allow for separation of the module **14** from the backplane. At the same time, the first and second ramp surfaces **74r1,74r2** of the lock member **74** slidably bear against the ejection surfaces **84a,84b** of the module **14** and displace the module outwardly away from the backplane **20** to a position where it will be freely separable

from the backplane (even if the lock member **74** is again released and allowed to return to its normal locked position before the module is lifted away from the backplane). The actuator portion **74k** of the lock member **74** is preferably defined with a recess **74s** that is adapted to receive a screw-driver blade or other tool **T** as shown in FIGS. 16A and 16B to facilitate movement of the lock member **74** from its locked position to its unlocked position as shown.

The device **10** comprises a seal associated with each mated pair of a base connector **30b1,30b2** with a module connector **60b1,60b2** to sealingly engage these connectors and prevent contamination of the contacts **30c,60c**. FIGS. 7, 8 and 11 illustrate one embodiment of a seal formed in accordance with the present development, wherein a seal **90** is associated with each module connector **60b1,60b2**. When the module connectors **60b1,60b2** are female socket-type connectors as shown, the seal **90** is located within the socket of the connector as shown. In this manner, when a module **14** is removed from the backplane **20** and replaced with a new module, the new module is supplied with a new seal **90**.

The seal **90** is explained with reference to FIGS. 17A-17C. As noted, a seal **90** is associated with each connector **60b1,60b2** of each module **14**. FIGS. 17A shows an inner housing **40a** of a module **14** and first and second seals **90** connected thereto (the male pin contacts **60c** are not shown). The seals **90** are recessed within first and second connector sockets **60d1,60d2** of the housing **40b**.

The seals **90** are each preferable defined as a one-piece molded polymeric construction using any suitable elastomeric or other resilient polymeric material (as shown the two seals **90** are also defined as a one-piece construction with each other and are interconnected by a web **90w**). In one embodiment, each seal **90** is defined as a one-piece molded construction from a thermoplastic elastomer (TPE) such as SANTOPRENE® brand TPE, but it is not intended that the development be limited to this material. It is possible for the seals **90** to be molded or otherwise constructed separately from the inner housing member **40a**, and then installed into the connector sockets **60d1,60d2** so as to be retained by a friction-fit, adhesive and/or other means. It

is deemed preferable, however, to utilize a two-step injection molding process: (i) a first step to mold the inner housing **40a**, including the sockets **60d1,60d2**; and, (ii) a second step to mold the seals **90** directly into the sockets **60d1,60d2**. This method reduces labor costs and is believed to result in a better connection of the seal **90** to the housing **40a**.

FIGS. 17B and 17C are sectional views that show one embodiment for the seal **90** and connection of same to the socket **60d1** (the seal **90** is connected to the socket **60d2** in a corresponding fashion). The socket **60d1** comprises an inner transverse wall **60e** through which a plurality of apertures **60f** are defined to allow for installation of contacts **60c** such as the male pins shown in FIG. 11 and elsewhere. The peripheral wall **60p** of socket **60d1** is generally cylindrical, and the seal **90** comprises a correspondingly generally cylindrical peripheral wall portion **90a** that is closely conformed to the socket **60d1**. The seal **90** also comprises an annular inner wall **90b** arranged transverse to the cylindrical portion **90a** and abutted with the inner wall **60e** of socket **60d1**. The annular inner wall **90b** of seal **90** defines a central opening **90c** that is aligned with the portion of the inner wall **60e** in which the apertures **60f** are defined to ensure that the seal **90** does not obstruct the apertures **60f**. The result of this structure is that the seal **90** has a generally L-shaped cross-section. If desired, the inner wall **90b** of seal can completely cover the inner wall **60e** of the socket and include apertures defined therein that are registered with the apertures **60f** of the socket inner wall **60e**. The outer end **90d** of seal **90** preferably diverges moving out of the socket **60d1** to facilitate insertion of a base connector **30b1,30b2**.

The inner wall **60e** of the socket **60d1** also defines flow passages **60g** and, during the two-step molding operation, the material from which the seal is defined flows through these passages **60g** and then cures, with the result being that the seal **90** is mechanically interlocked with the socket **60d1** and anchored therein. Depending upon the particular materials from which the seal **90** and housing **40a** are molded, the seal **90** can also be adhered to the socket **60d** and/or chemically bonded thereto as a result of the two-step molding operation.

The seal **90** comprises at least one and preferably at least two sealing elements that provide two different, transverse sealing dynamics. As shown, the seal comprises a radial sealing element for sealingly engaging radially or laterally adjacent surfaces and an axial (compressive) sealing element for sealingly engaging axially adjacent surfaces.

The radial sealing element comprises at least one continuous radial lip **92** that projects radially inward from the peripheral wall portion **90a** toward a central region of the socket **60d1**. The one or more radial lips **92** are adapted to abut and sealingly engage the outer cylindrical or conical surfaces **36b1,36b2** (FIG. 2) of an associated base connector **30b1,30b2** inserted in the socket **60d1**. If the associated base connector **30b1,30b2** is frusto-conical as described above, it has been found to facilitate insertion and removal of the base connector **30b1,30b2** relative to the socket **60d1** without compromising the effectiveness of the radial sealing element **92**.

The axial sealing element comprises at least one continuous axial lip **94** that projects axially outward from the inner wall **90b** of the seal **90** into the socket **60d1** toward the entrance **60h** of the socket. The one or more the axial lips **94** are adapted to abut and sealingly engage the transverse end wall **38a,38b** (FIG. 2) of an associated connector **30b1,30b2** inserted into the socket **60d1**.

The combined radial and axial sealing has been found to be highly effective. The effectiveness of the radial and axial sealing elements are enhanced owing to the use of the coupler **70** for coupling the removable modules **14** to the backplane **20** to ensure good and continuous engagement of the radial seal element **92** with connector surfaces **36b1,36b2** and the axial seal element **94** with connector surfaces **38b1,38b2**, respectively. Furthermore, the module ejection function of the coupler **70** that displaces the module **14** away from the backplane **20** as described above helps to overcome the sealing engagement between the module **14** and the backplane **20** established by seal **90** that can otherwise hinder separation of a module **14** from backplane **20**.

FIGS. 18A,18B illustrate an alternative embodiment where a seal **190** is connected to a base connector **30b1** instead of being located in a socket **60d1,60d2** of module **14** (the same arrangement can be applied to a base connector **30b2**). The seal

190 is similar to the seal **90** in that it comprises a first portion **190a** that is closely conformed to and covers at least part of the outer surface **36b1** of the connector. The seal **190** also comprises an annular outer wall **190b** arranged transverse to the first portion **190a** and abutted with the outer transverse wall **38b1** of the connector **30b1**. The annular outer wall **190b** of seal **190** defines a central opening **190c** that is aligned with the portion of the outer transverse wall **38b1** in which the apertures **39** are defined to ensure that the seal **190** does not obstruct the apertures **39**. The result of this structure is that the seal **190** has a generally L-shaped cross-section. If desired, the inner wall **190b** of seal can completely cover the transverse wall **38b1** of the connector **30b1** and include apertures defined therein that are registered with the apertures **39**.

The seal **190** comprises at least one and preferably at least two sealing elements that act in transverse directions relative to each other. As shown, the seal comprises a radial (lateral) sealing element and an axial (compressive) sealing element.

The radial sealing element comprises at least one continuous radial lip **192** that projects radially outward from the seal first portion **190a**. The one or more radial lips **192** are adapted to abut and sealingly engage an inner surface of the socket **60d1** in which the base connector **30b1** is inserted.

The axial sealing element comprises at least one continuous axial lip **194** that projects axially outward from the outer wall **190b** of the seal **190**. The one or more axial lips **194** are adapted to abut and sealingly engage the inner wall **60e** (FIG. 2) of socket **60d1** when the base connector **30b1** is inserted into the socket.

FIGS. 19A and 19B illustrate an alternative device **210** that is identical in all respects to the device **10**, except as otherwise shown and/or described. Like components relative to the device **10** are identified with like reference numerals that are **200** greater than those used in connection with the device **10**. The device **210** comprises a backplane **220** that is identical to the backplane **20** except that the base connectors **230b1,230b2** are female socket connectors comprising male pin contacts **230c**. Modules **214** are adapted for releasable connection to the backplane **220** as described above for the modules **14**, except that the module connectors **260b1,260b2**

are male plug connectors including female contacts **260c**. The device **210** comprises either seals **90** located in the sockets **230b1,230b2** or seals **190** connected to the plug connectors **260b1,260b2**.

The invention has been described with reference to preferred embodiments. Modifications and alterations will occur to those of ordinary skill in the art, and it is intended that the claims be construed literally and/or according to the doctrine or equivalents to encompass all such modifications and alterations.